Accessing User Facilities and Making Your Research Experience Successful

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New users at the Advanced Photon Source receive facility orientation and safety training before starting their experiments. PHOTO COURTESY OF GEOSOILENVIROCARS, UNIVERSITY OF CHICAGO

Access to many of the world's leading user facilities is easier than ever before, with web-based tutorials providing everything from instrumental overviews and example applications to online safety training. Submission of proposals for experiment time at large, heavily subscribed facilities, including synchrotron and neutron sources, has been streamlined with web-based submission. Support, which is commonly the key to successful experiments, is provided by facility staff and experienced users, allowing new users to begin experiments with minimal experience. Increasingly Earth scientists are taking advantage of the wide range of unique instrumentation at user facilities. Here, we explain how you can, too.

KEYWORDS: user facilities, synchrotron, neutron source, electron microscopy, user access, safety training

INTRODUCTION

A research facility is most valuable if it is available when we wish to use it and if it provides a level of user support that maximizes the likelihood of experimental success. The necessary support must include adequate user training, but it should also ensure that the instrumentation is running optimally and accommodates individual experimental needs. Let's not overlook safety, which may be as important to the continuing operation of the facility as it is to the success and well-being of the user. Meeting these goals is quite a challenge, one that requires effective organization, management, and resources. Today, most successful research facilities are heavily subscribed by users and operate with limited, hard-earned funding. Consequently, access generally requires prior approval and justification, often involving merit-based review. Although some users are able to complete their experimental project after one visit to a facility, many find it necessary to make return visits, with some becoming regular users. In this article, we describe access styles, management models, and aspects of user support at research facilities. We focus mainly on large, heavily subscribed user facilities, such as synchrotrons and neutron sources, which offer a wide variety of experimental techniques and have large user communities. Our goal is to offer potential new users in the Earth science community a better understanding of the path to using research facilities and the resources they provide. Because the specific policies of each facility may differ, the description we provide should be considered as a starting point only, and users should investigate facilities of interest further.

So, you'd like to use an ion microprobe to determine the oxygen isotopic difference between a microscopic inclusion and its host mineral, or you need to use a synchrotron facility beamline to characterize the chemical speciation of chromium in a contaminated soil. Just hop on a plane, show up at the front door, and before you finish your first cup of coffee a cheerful staff scientist is already mounting your sample on the stage!

Wake up… were you dreaming?

In preceding articles, different classes of user facilities were described, including large multi-instrument laboratories, such as the Environmental Molecular Science Laboratory (EMSL) at Pacific Northwest National Laboratory and the several planned US nanocenters; synchrotron radiation and neutron sources, such as the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory and the neutron facility ISIS at the Rutherford Appleton Laboratory (UK); and individual instruments typically located at universities. Some large facilities have a particular scientific focus and support multiple types of instrumentation, examples being the EMSL and the Bayerisches Geoinstitut in Bayreuth (Germany). In contrast, synchrotron, neutron, and electron beam facilities offer techniques specific to their source characteristics but support users from diverse scientific disciplines. The infrastructure and management of larger facilities are generally dictated by the size of the facility and user community, as well as by the funding source. Individual instruments or small collections of instruments that are made available to external users are typically housed in university departments and overseen by the department or sometimes an individual investigator.

Large user facilities are generally government funded and provide instrumentation and experimental capabilities whose costs for construction and operation are beyond the means of individual research groups or even universities. Good examples are the user facilities funded and managed by the US Department of Energy's Office of Science. These state-of-the-art facilities are available to the science community worldwide and offer some technologies and instrumentation not available elsewhere. They include particle and nuclear physics accelerators, synchrotron light sources, neutron scattering facilities, electron beam facilities, supercomputers, and high-speed computer networks. Access is

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typically determined by merit-based review of proposals, the necessary training and experimental oversight are provided by the facility itself, and no user fees apply to access the facility and conduct the experiment (although ancillary costs are covered by the user).

WOULD MY RESEARCH BENEFIT FROM ACCESS TO A USER FACILITY?

For many Earth scientists, a significant hurdle is recognizing the availability of techniques that could benefit their research project. Technique development has traditionally not been as strongly promoted in the Earth sciences as in other fields, such as physics. Consequently we often learn about emerging techniques only after they have been developed and applied in other fields. Peer-reviewed publications are an important avenue for disseminating information about emerging technologies and techniques available to Earth scientists at user facilities. Also valuable are short courses and workshops, such as those sponsored by the Mineralogical Society of America, the Geochemical Society, and the European Mineralogical Union. For example, upcoming or recent short courses have highlighted neutron scattering in the Earth sciences (2006) and the applications of synchrotron radiation in geochemistry (2002).

Nearly all user facilities provide informative web pages describing aspects of their operation. Many facilities even offer online tutorials that serve as introductions to scientific approaches or applications of methods to different problems. *Facility web pages should be the first point of information for any new user.* In addition, new "first point of contact" websites are emerging, such as www.envirosync.org, which provide information on facilities specializing in particular areas of science.

ARRANGING EXPERIMENT TIME AT A RESEARCH FACILITY

Access to most facilities generally requires submitting a proposal beforehand. This applies for all synchrotron and neutron facilities and most electron beam characterization facilities. Exceptions may include smaller facilities or single instruments, where access may commonly be arranged informally. Here we describe some general aspects of access policies and the proposal process, focusing primarily on synchrotron and neutron facilities, which have large, diverse user communities representing nearly all science, engineering, and health disciplines and spanning academic, industrial, and private foundation sectors.

Access for outside users is primarily based on scientific merit, usually as determined by peer-review of proposals. The process begins with identifying the appropriate facility for your experiment (FIG. 1; STEP 1). Importantly, the facility web pages usually provide contact information so that potential users can discuss their research needs with experienced scientists and support personnel to determine if a method is suitable for providing the information desired. In instances where scientific staff are unfamiliar with the particular nature of your Earth science problem, further inquiry may be required, perhaps with Earth scientists with prior experience.

An access proposal is then developed. It is normally brief (1–4 pages) and includes a description of the scientific question to be addressed and its significance, justification for a requested instrument or experiment station, and a request for a specific amount of experiment time. Most synchrotron and neutron facilities have gone to great lengths to streamline the proposal process, with submissions made online through easy-to-follow web pages. After submission (STEP 2), a proposal is either reviewed by a panel of scientists or sent

FIGURE 1 Generalized process for obtaining access to large user facilities, such as synchrotron and neutron centers.

out for external review (STEP 3). Owing to the range of techniques available at synchrotron facilities, multiple review panels are used to evaluate proposals. For example, at the National Synchrotron Light Source (Brookhaven National Laboratory), the review process uses as many as 12 separate subpanels to evaluate proposals (TABLE 1). Each facility has developed its own procedures, which are explained on their web pages.

Proposals are reviewed for scientific merit and technical feasibility and assigned a numerical rating. Depending on the scope of each facility's panels, proposals from Earth scientists may be rated along with those from other fields, based on the technique to be employed. New users should be aware that some review panels may not have Earth scientists as members. If such proposals are not sent out for external reviews, they may be reviewed by scientists with expertise in the chosen method but with limited knowledge of Earth science issues. Therefore, Earth scientists may want to include sufficient explanation and justification in their proposals to allow experts from other disciplines to make a fair evaluation. The scientific question to be addressed, the relevant hypothesis, and the significance of the research should all be emphasized. It is also important to justify the use of the requested instrument or experimental beamline, since the total time requested by all users may exceed what is available. As more Earth scientists become regular users of synchrotron, neutron, and electron beam facilities, it is encouraging to see our representation on review panels increasing. In some instances factors other than scientific merit alone may influence ratings; these might include feasibility, time or resources requested, and prior results. Review panels nearly always provide users with comments on their proposals.

After the review process, allocations are made, with available beamtime generally being assigned first to the proposals having the best ratings (STEP 4). Users are then informed of their allocation, specific dates are assigned for the experiment through interactions with the facility staff, and the experiment is conducted (STEP 5). At heavily subscribed facilities or beamlines, requests often exceed available time. Unfortunately, this means that some proposals may not be allocated experiment time for the requested period or cycle. In our experience, allocation panels usually go to great lengths to achieve a fair and optimal balance in assigning

beamtime. For example, it is common for even the best-rated proposals to be restricted in the amount of beamtime, in order to accommodate additional users. First-time users often do not have a good sense of how much time they can reasonably request. Contacting the experimental staff beforehand can be invaluable in assuring that your request for time is not deemed excessive. In cases where first-choice beamlines or instruments are oversubscribed, a user may be allocated time at other beamlines or instruments with comparable capabilities.

TABLE 1 PROPOSAL REVIEW PANELS AND SUBPANELS AT THE NSLS

- **Imaging and Microprobes**
  - Biological and Medical
  - Chemical and Material Sciences
  - Environmental and Geosciences
- **IR/UV/Soft X-ray Spectroscopy**
  - Chemical Sciences/Soft Matter/Biophysics
  - Magnetism/Strongly Correlated Electrons/Surface
  - Methods and Instrumentation
  - Macromolecular Crystallography
  - Powder/Single Crystal Crystallography
- **X-Ray Scattering**
  - Magnetism/Strongly Correlated Electrons/Surface
  - Soft Matter and Biophysics
- **X-Ray Spectroscopy**
  - Biological, Environmental and Geosciences
  - Chemical and Material Sciences.

Most synchrotron and neutron facilities have two or three cycles of submission, review, and allocation per year. This provides several target deadlines for submission of proposals. At many facilities, a user may choose to submit a proposal that remains active for up to two years rather than being applicable to a single cycle; however, separate requests for experiment time must be made for each cycle. The total process—from submission to actual experiment—may range from three to eight months, depending on the operating schedule of the facility. Using the Advanced Photon Source (APS) at Argonne National Laboratory (USA) as an example, a user would submit a proposal by the mid-July deadline to be considered for experimental beamtime in the October through December cycle. These access models require awareness of the proposal process and advance planning. The web page lightsources.org provides information about proposal deadlines for all the world's synchrotrons.

If a user has a particular project that simply cannot wait for a typical submission and review process, some facilities offer a rapid access option, which may provide experiment time in as little as days to weeks. However, this rapid access is reserved for circumstances where timeliness is crucial to an experiment and must be well justified.

New users should be aware that most of the large research facilities require approval and notification prior to arrival, and issue identification badges on site. At all research facilities in US national laboratories, non-US citizens are subject to further security and clearance scrutiny. In short, it is essential to consult facility web pages or representatives to determine access requirements well before experiments are actually scheduled. Although facilities strive to improve the speed of this process, it may still require months for scientists from certain countries to receive clearance. Even though the US Department of State continues to re-assess the timely issuance of visas to visiting scientists (Flatten 2005), further reforms may require a stronger voice from US scientists who seek more effective international collaborations.

HOW MUCH TIME IS AVAILABLE AT A USER FACILITY?

Having forewarned readers that they should not expect unlimited experimental time at large user facilities, it is useful to consider some of the additional constraints that determine how much time is actually made available to external users. Facilities such as synchrotrons and neutron sources routinely set aside time for maintenance, upgrades, and studies of source characteristics. The fraction of time available to outside users not only varies among facilities but also among the experiment stations within a facility, depending on the technique(s) implemented, their development and maintenance needs, and management style. Many of the large scientific facilities "work concurrently in two modes—operating the overall facility and operating the experimental stations within the facility" (Kelly et al. 2003). The facility itself assumes responsibility for overall operations, stability, maintenance, and upgrades. For most users, however, their experience at the experimental stations is critical for the success of their experiment. In many cases these end-stations and their instruments are operated by the facilities themselves, encompassing design, development, and maintenance, as well as providing experiment time to outside users. Typically the fraction of user time at facility-operated stations is 50–85% of the total available. This mode of operation maximizes the time available to users and allows the facility to pool its technical expertise among various beamlines.

At some user facilities, however, a consortium of scientists or an external organization may use independent funding to design and operate an experimental station, thereby assuming responsibility for design, development, and maintenance. Because the member scientists secured funding and undertook this responsibility in order to conduct their own research projects, they have generally negotiated with the facility for a certain allocation of experiment time to accommodate their own needs and still provide time for external users. Consortia may also receive funding to support a specific scientific community, making all of the beamtime available to external users. Hybrid models combining components of both styles also exist. Although less overall time may be available to external users in these cases, these consortium-operated experimental stations offer more specialized user support and innovation in instrument development. Because funding for such groups often comes from programs with a particular research focus, these experimental stations can be optimized for particular research needs or modified to accommodate specialized instrumentation suited to the focus area. For example, synchrotron experimental stations that are partly supported by the US National Science Foundation's Earth Sciences Program and the US Department of Energy's Geosciences Research Program have Earth scientists as full-time staff and house unique instrumentation, one example being large presses for in situ studies of mineral samples at high pressure and high temperature. This level of specialization specifically serves the Earth science community. Facility- and consortium-operated experimental initiatives each have their own merits and both should be encouraged.

At electron beam characterization facilities supported by the US Department of Energy's Office of Science, there are no instrument cycles, and proposals are welcome at any time. However, they should generally be submitted two

months prior to requested experiment time. Some electron beam characterization facilities give priority usage to in-house staff, with experiment time available to external users on request. The majority of instrument time at the Center for High Resolution Electron Microscopy at Arizona State University is used by in-house scientists, but this facility also has many external users. The Instrument National de Microscopie Electronique en Sciences de la Terre (French National TEM Facility in Earth Sciences), with locations in Lille and Marseille (France), provides electron microscope access primarily to scientists at supporting laboratories of the Centre National de la Recherche Scientifique (CNRS), but access is also available to outside users.

Because the available experimental time at large facilities is so limited, careful planning of experiments and preparation of samples are essential. Assembling a small team often works best, allowing researchers to work in shifts, which is particularly useful for 24-hour, 7-days-a-week operations. Many experimental stations allow automated data collection over extended periods of time, permitting users to take extended breaks.

SO, WHAT DOES IT COST?

The great news is that many facilities have no user charges. In other words, the actual experiments are free for approved users, except for proprietary work. This includes all of the synchrotron and neutron facilities throughout the world, and any of the user facilities supported by the US Department of Energy, such as the Environmental Molecular Science Laboratory at Pacific Northwest National Laboratory and the National Center for Electron Microscopy at Lawrence Berkeley National Laboratory. The philosophy underlying this free access is that the research ultimately benefits the taxpayers who have paid for it. Consequently, it is incumbent on the academic, industrial, and government scientists using these facilities to publish their findings in the open literature. Government-funded facilities also make experiment time available for proprietary research. Such users request confidentiality of proposal, data, and results for a certain period of time, and usually are required to pay for access.

Most facilities operating within universities and nearly all single-instrument labs have user charges, which is not surprising in view of their limited funding base. For example, access to electron microscopes at most facilities incurs user charges (except at US DOE facilities), which vary in amount. Users at the Bayerisches Geoinstitut (University of Bayreuth, Germany) are expected to cover the basic cost of their research, although charges may be reduced when the research is conducted in collaboration with Geoinstitut scientists. In addition, users from European Union countries (except for Germany) may apply to the Geoinstitut for EU support to cover travel, subsistence, and experimental costs. Users pay a modest fee at the Northeast National Ion Microprobe Facility, located at Woods Hole Oceanographic Institute in Massachusetts (USA); however, discretionary funds are sometimes made available. The Purdue Rare Isotope Measurement Laboratory (PRIME Lab), located in West Lafayette, Indiana (USA), provides accelerator mass spectrometry analyses for a modest fee, but also accepts applications for a limited number of initial analyses done free of charge.

USER SUPPORT AT RESEARCH FACILITIES

Now that you've obtained access to a user facility, how do you make sure your experiments will be successful? New users will find themselves working with instrumentation that is unfamiliar (at least initially) and complex. The physical environment of synchrotron and neutron facilities may appear daunting, with a seemingly endless maze of electrical wiring and cables, vaccuum systems, lead shielding, and interlock systems. Work practices in a user facility can be quite different from those found in many university Earth science departments. For example, at synchrotron facilities, experiments are conducted continuously when the beam is available (i.e. 24/7). Although many new users know the principles behind the instrumentation and the method, they usually lack the hands-on operational knowledge required to make the most effective use of experimental time, to obtain the highest quality data, and to interpret it properly. This is when user support becomes crucial and is often the key to a successful research experience.

FIGURE 2 Beamline scientists and technical staff provide support allowing new users to maximize the effectiveness of their experiment time. Here, NSLS scientist Lisa Miller (center) shows new users how to operate software. PHOTO COURTESY OF BROOKHAVEN NATIONAL LABORATORY

Learning how to Operate the Equipment

During the first visit to a large facility, a significant amount of time is invested in familiarizing the users with the facility and training them in the mechanics of conducting the experiment. This may include aspects of instrument operation, software usage, sample mounting and preparation, data quality optimization, and data collection and interpretation. While some general familiarization with the facility can be accomplished by group training or by computer-based tutorials, the training needed to operate instrumentation safely is provided on an individual basis by a facility scientist or staff member who works specifically at that experimental station (FIG. 2). In some cases, users may be given initial training and then allowed to take over the controls for their experiment time, with the support staff available if problems arise. In other instances, a support staff member may actively assist users during the entire duration of their experiments. As users become more expert and require less support, the level of involvement usually decreases. Most user facilities strive to provide an optimal level of support for outside users; however, adequate fund-

ing for support staff may be a limiting factor. For example, the number of support staff available to help outside users at synchrotron beamlines may range from less than one (i.e. part-time) to more than four.

In our experience, users benefit greatly from collaboration with facility staff, and we strongly encourage new users to develop such collaborations. This can be particularly beneficial when the facility staff includes someone with an Earth sciences background. The quality of publications is often greatly enhanced by such collaborations.

Some facilities supplement hands-on training through their websites. Thus, users may familiarize themselves with instrumentation and operations prior to their arrival at the facility. These websites are also valuable for answering questions that arise during and after an experiment, particularly with regard to data processing and interpretation once the user has left the facility. At some facilities, web-based tools have even made it possible to conduct experiments remotely, with local staff mounting and removing samples mailed by the user.

Safety Training

Not only must users familiarize themselves with the mechanics of the actual experiment, they must also comply with safety and training requirements of the facility. Protection of personnel and the environment is the highest priority at all user facilities, and great efforts have been made to ensure that work is conducted safely. Large facilities, including all synchrotrons, require users to take regular safety training courses covering safety aspects relating to the facility and to general radiological hazards. Much of this safety training is available online, allowing users to satisfy these requirements on arrival or even before arrival at the facility. Additional training may be required if experiments involve specific hazards, such as use of radioactive substances or certain electrical equipment.

All activities are planned and conducted in accordance with stated safety policies. At synchrotron and neutron facilities, a user's proposed experiment undergoes an experiment safety review prior to receiving authorization. These mandatory reviews may be quite rigorous and are intended to ensure that risks are minimized through proper design and operation of equipment and proper handling and disposal of materials. Safety staff members are highly experienced and can provide valuable assistance to users in the design of equipment or material handling. *We can't stress enough how important it is to have a dialog with safety staff in the early stages of planning your experiment.*

Safety and beamline staff can also make users aware of shipping, handling, and labeling requirements, to ensure that samples will be allowed into the facility and that they are handled safely during the experiment. By following the correct protocols, it can be relatively easy to work even with radioactive and toxic samples at most facilities.

Outreach and Education

Regular users of research facilities are some of the best resources for information about specific techniques and applications, and are also potential collaborators for new users. Large facilities regularly host short courses and hands-on workshops, which serve to introduce new users to different methods and also permit experienced users to exchange ideas. Such workshops are very popular in the biosciences and have proven to be a critical training resource. Typically held over a span of several days, they allow for in-depth coverage of topics and an opportunity for researchers to collect data. Relatively few workshops have focused exclusively on applications to the Earth sciences. One recent example was a workshop sponsored jointly by the Mineralogical Society of America and the Geochemical Society, resulting in a publication in the *Reviews in Mineralogy and Geochemistry* series (Fenter et al. 2002). The Mineralogical Association of Canada has also published several short course volumes covering Earth science applications of facility-based techniques (e.g. Henderson and Baker 2002). Two groups of synchrotron users in the Earth and environmental sciences—GeoSync (millenia.cars.aps.anl.gov/geosync) and EnviroSync (envirosync.org)—serve as advocates for increased involvement and support for these valuable resources. The latter group has co-sponsored a series of workshops, entitled "Synchrotron Environmental Science," highlighting new synchrotron applications in environmental science, and has also held workshops for new users. National meetings of Earth science and sister societies also provide valuable opportunities to highlight research applications using the unique instrumental capabilities at user facilities. We hope that professional societies, government funding agencies, and user-based initiatives will continue to make Earth scientists aware of opportunities for novel research opportunities at the world's user facilities. The small investments required to sponsor such workshops have enormous payoffs in later research.

This overview has shown that gaining access to research user facilities is relatively simple. With the many interesting techniques they have to offer, there is likely to be something that can benefit your research. Moreover, by conducting high-quality research at government-supported user facilities, you will be contributing to their continued success.

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